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STRUCTURAL AND STRATIGRAPHIC CHRONOLOGY OF THE TACONIDE AND ACADIAN POLYDEFORMATIONAL BELT OF THE CENTRAL TACONICS OF NEW YORK STATE AND MASSACHUSETTS

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Introduction

On this trip we will examine selected features of the Taconic rocks that have a bearing on deciphering the complex depositional and tectonic events that have affected these rocks. The traverse at 42°15 N. latitude extends from the low Taconics near the Hudson River, east to the high Taconics of Massachusetts. The discussion, rather than being complete, is selective and stresses new evidence not previously treated. For a general discussion, see Trip B-1. Some controversial questions will be raised; we hope to stimulate new interest in Taconic geology by pointing out some of the major unsolved problems that remain to be studied in this and presumably other parts of the Taconic allochthon.

In the past decade major advances in our conceptual knowledge of the Taconic geology have been made largely by the efforts of E-an Zen (1961, 1967, 1972), Bird and Dewey (1970), and Bird and Rasetti (1968). As a result of these studies, a unified picture has evolved that is elegantly simple but at the same time incredibly comprehensive. However, some of the Taconic rocks are exceedingly complex, and many unresolved problems remain to be studied.

For a recent summary of the geology of the Giddings Brook slice at this latitude see Bird and Dewey, Trip B-1.

Zen (1967) has proposed that the allochthonous rocks of the Taconics belong to six or seven discrete structural slices (fig. 1) that overlap eastward so that the highest structural level, the Dorset Mountain slice, in western Massachusetts, known as the Everett slice (Ratcliffe, 1969), crops out at the east edge of the allochthon. Rocks of the Everett slice constitute the high Taconic sequence at this latitude and are presumed to have been emplaced last.

The low Taconics here are represented by rocks of the Giddings Brook, Chatham, and Rensselaer Plateau slices according to Zen (1967). The distinction between high and Taconic is based in part on topographic expression, relative structural position, and stratigraphic considerations and implies no one specific tectonic or stratigraphic attribute. The terminology is imprecise and probably has outlived its usefulness.

Zen further proposed that the stratigraphic range of the individual slices is greatest in the lowest slices and most abbreviated in higher

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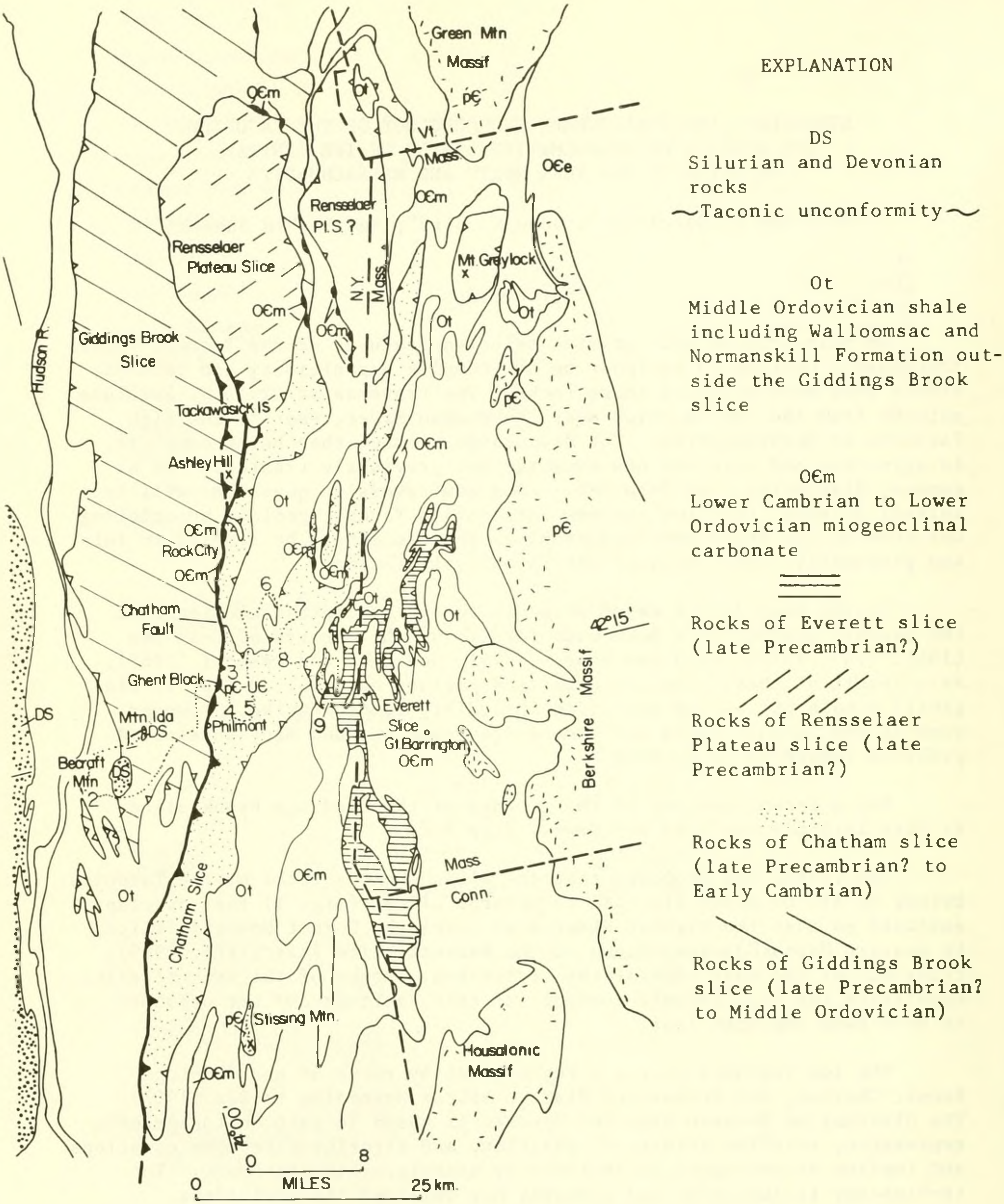

Figure 1. Regional geologic map showing slices of the Taconic allochthon modified from Zen (1967), based on data in Ratcliffe (1974a), Ratcliffe and Bahrami (in press), and Potter (1972). The Chatham fault is shown with solid triangles; extensions north of Rock City and south of Philmont are conjectural.

slices, which contain rocks largely of inferred late Precambrian age (Zen, 1967). The lowest and westernmost slices, the Giddings Brook and Sunset Lake (in Vermont), were emplaced by gravity gliding in the Middle Ordovician, contemporaneously with wildflysch-like (Forbes Hill Conglomerate) material that contains fossiliferous and nonfossiliferous fragments of the allochthon itself. Graptolites of Zone 13 (Berry, 1962, p. 715) in the matrix of the wildflysch-like conglomerate that underlies the Giddings Brook (East Petersburg slice of Potter, 1972) and Sunset Lake slices date the time of submarine emplacement (Zen, 1967; Bird, 1969). Graptolites of Zone 12 (Berry, 1962) have been collected from the Walloomsac Formation which underlies wildflysch-like conglomerate at the eastern (trailing) edge of the Giddings Brook slice (North Petersburg slice) at Whipstock Hill (Potter, 1972). This suggests that the Giddings Brook slice was emplaced during the timespan represented by Zones 12 and 13, although the lack of fossils in the matrix at Whipstock Hill precludes proof of this point.

The Chatham slice overrides the Giddings Brook slice along the Chatham fault of Craddock (1957) (fig. 2). The fault zone contains slivers of carbonate and other rocks (see discussion, Stop 3) that were thought to have been plucked from the autochthon during emplacement in Sherman Fall time (Zen, 1967, p. 34). To the east, the Chatham slice is overlain by the Everett slice at the sole of which are distinctive tectonic breccias that consist of complex mixtures of fragments of all the shelf sequence carbonates, and Walloomsac and Everett, lithologies concentrated along the soles of imbricate slices (Zen and Ratcliffe, 1968; Ratcliffe, 1969, 1974a) (Stop 9).

Chatham slice and the Chatham fault

The rocks of the Chatham slice were studied previously by Craddock (1957) and Weaver (1957), who did not map detailed stratigraphy within the slice. Thus Zen in his 1967 compilation had only limited data available bearing on Chatham slice stratigraphy.

The results of recent detailed mapping in two quadrangles spanning the width of the Chatham slice are shown in Figure 2. Rocks of the Chatham slice resemble closely gray-green and purple slate (Mettawee), Rensselaer graywacke, and other rocks of the Nassau Formation (Bird, 1962a) in the Giddings Brook and Rensselaer Plateau slices (Table 1). The Chatham slice sedimentary rocks (Nassau) probably also are pre-Olenellus in age. Distinctive but sporatically developed diabasic basalts, pillow lavas, and pyroclastic volcanic rocks are spatially associated with the base of the Rensselaer facies in all three slices (Balk, 1953; Potter, 1972; Ratcliffe, 1974a).

Massive quartzites similar to the Zion Hill (Zen, 1961) and Curtis Mountain quartzites (Fisher, 1962) crop out in the Chatham slice within the areas denoted by Ɇnsq on Figure 2. However, the quartzites mapped in the Chatham slice in both the State Line and Chatham quadrangles underlie

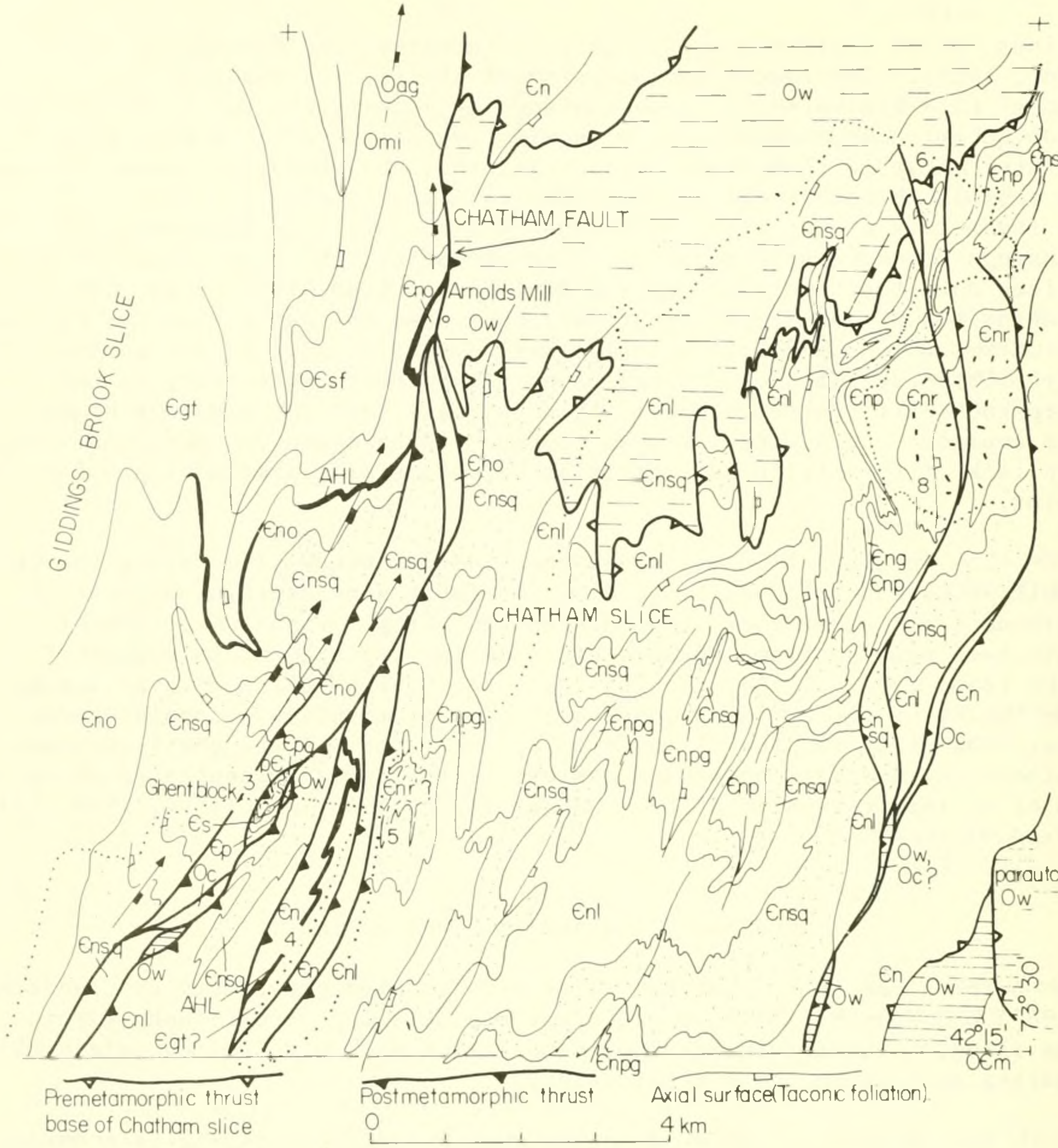

Figure 2. Generalized geologic map of the contact relationships between the Giddings Brook, Chatham, and Everett slices of the Taconic allochthon in the Stottville and Chatham, New York, and State Line and Egremont, Massachusetts and New York, quadrangles. Saw teeth indicate thrust fault, teeth on upper plate; open triangle indicates a premetamorphic fault; solid teeth indicate postmetamorphic (post-Taconic) fault. Maps join at 73°30' W. longitude. Field trip route, Stops 3 to 9, indicated by dotted line.

Ensq
OЄs
Env Ensq
Ow
Єnp
Єnsq
Єnr
Єnr
Ow
Єnp
Fog Hill
Ow
Єnv
Єev
OЄs
tb
CHATHAM SLICE
Ow
EVERETT SLICE
Єev
Єnsq
tb
Єev
Єn
Ow
Єn
Ow
parautoc Ow
Єev
tb
tb
tb
tb
42°15'
73°30'
OЄs
Єev
9
tb
Єev
Єev
Ow
OЄs
OЄs
EXPLANATION
Bedrock of Autochthon
Mid. Ord
Low.C to Low. Ord
Ow
Walloomsac Formation
OЄs
Stockbridge Formation
tb
tectonic breccia at sole of Everett slice composed of blocks of OЄs, Ow, and Єev intermixed
Bedrock of allochthon
Giddings Brook slice
Lower Cambrian to Middle Ordovician
Oag
Austin Glen Graywacke
Omi
Indian River-Mount Merino
OЄsf
Stuyvesant Falls Formation
Єgt
Germantown Formation
AHL
(Ashley Hill Limestone conglomerate, Mudd Pond Quartzite)
Cambrian?
Єno
Olive Siltstone of Nassau Formation
Єnsq
Green slate, quartzite and siltstone of Nassau Formation
Chatham slice (shows schematic west to east facies relationships)
West
East
Cambrian ?
Єnsq
Green slate, quartzite siltstone with conglomerate
Єnr? Curtis Mountain Quartzite?
Єnl
Well laminated green, gray slate
Єnpg
Purple and green slate
NASSAU FORMATION
Єnr
Rensselaer graywacke
Єnv
basalt flows, andesite?
Єnsq
Green slate siltstone quartzite
Єnp
Purple slate
Everett slice
Cev
(may be equivalent to lower part of Nassau Formation)
Cambrian ?
Green, gray, purple and green phyllite with minor beds of graywacke and greenish quartzite; blue quartz pebble conglomerate, albitic phyllite

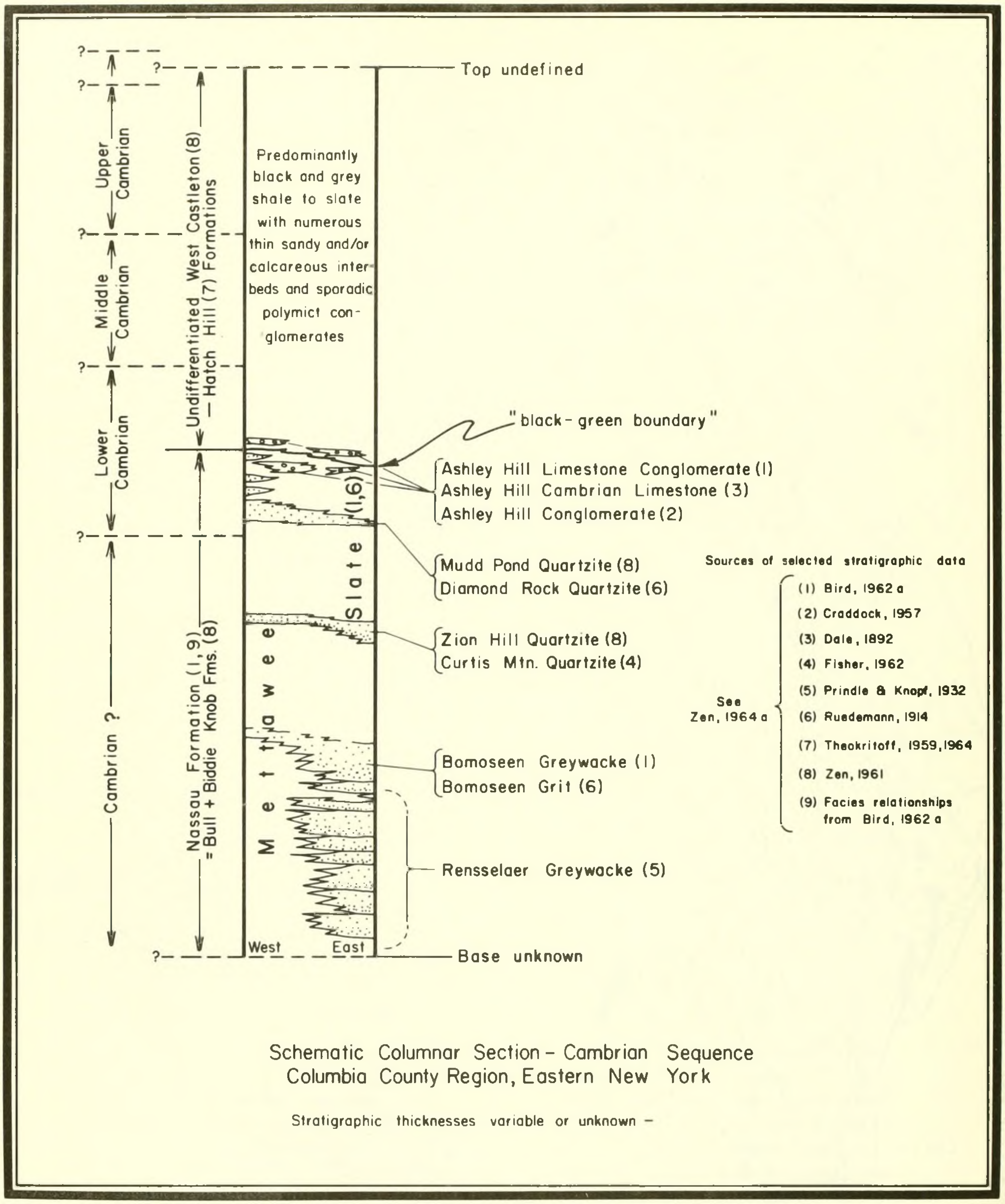

Table 1. Stratigraphic sequence of Cambrian rocks in the Giddings Brook and Rensselaer Plateau slices of Columbia County, New York. Reproduced from Bird and Rasetti (1968). Stratigraphy of similar rocks of the Chatham slice is shown in the explanation of Figure 2.

the Rensselaer-type graywackes. One of these quartzites with a polymict basal conglomerate (Stop 5) contains angular fragments of basaltic or andesitic scoria, suggesting that the relatively thin subgraywackes and quartzites exposed in the western part of the Chatham slice may be tongues of Rensselaer-like material that extended westward into the sedimentary basin.

Importantly, the Rensselaer-like graywacke of the Chatham slice in the Austerlitz outlier and in the State Line quadrangle overlies a considerable thickness (2,000 to 2,500 feet) of purple and green slate, siltstone, and laminated green slate typical of the Nassau elsewhere. However, Rensselaer graywacke of the Giddings Brook and Rensselaer Plateau slices appear at or near the base of the preserved stratigraphic succession (Table 1). The stratigraphic position of the Rensselaer within the original (as opposed to the allochthonous) sequence is really moot, because the original sequence is nowhere preserved intact, and we do not know at present if the Chatham relationships are the rule rather than the exception.

Rocks probably as young as the Ashley Hill Limestone and the West Castleton-Hatch Hill sequence have recently been discovered (Stop 4) by Bahrami within the area of the Chatham slice as shown by Zen (1967), who used Craddock's (1957) location of the Chatham fault, the westernmost fault on Figure 2. At present we believe this sequence is a large fault sliver rather than a proven part of the Chatham slice stratigraphy. Figure 2 shows that stratigraphic units common to each slice are contiguous along the Chatham fault zone south of Chatham, and Nassau stratigraphy in the two slices overlaps.

The internal structure of the Chatham slice is complex and not fully understood at present. Although no major recumbent folds are recognized, a series of F_1 folds older than the slaty cleavage is present (fig. 2). From Arnolds Mills eastward, the rocks of the Chatham slice clearly overlie the Middle Ordovician Walloomsac, based on the detailed analysis of minor structures by Bahrami. Locally a wildflysch-like conglomerate is present within meters of the contact (Stop 6). The regional Taconic slaty cleavage crosscuts the thrust, and the contact is folded into northwestward overturned folds. The allochthonous nature of the Chatham slice has been demonstrated by geometric relationships (Ratcliffe, 1969, 1974a; Ratcliffe and Bahrami, in press), and the field relationships are compatible with emplacement in the Middle Ordovician. The wildflysch-like rock seen at Stop 6 supports this conclusion.

Detailed mapping in the Chatham and Stottville quadrangles has shown that the Chatham fault (contact between the Giddings Brook and Chatham slices) is a late tectonic feature and that the original Ordovician boundary between the two slices may no longer exist intact. The Chatham fault is a major post-Taconic (post-slaty cleavage) thrust that encorporates fragments of shelf carbonates, pieces of the Chatham and Giddings Brook slices, and a block (Ghent block) of Grenville gneiss with attached rocks of the shelf sequence (Stop 3). Because of the demonstrable late origin of the Chatham fault, and because of the overlap in Nassau stratigraphy, no direct evidence requiring that the Giddings Brook and Chatham slices be separate slices is known. Ratcliffe and Bahrami (in press) suggest that they were continuous prior to imbrication in the Chatham fault.

Because of the geometric relationships cited above and the extensive overlap in Nassau stratigraphy among all three slices, it does not seem likely that the Giddings Brook and Chatham slice rocks were deposited directly above the rocks of the Rensselaer Plateau slice (Zen, 1967, p. 67) in the Taconic depositional basin. The rocks of the Rensselaer Plateau slice that now overlie the Giddings Brook slice (Potter, 1972) could have been deposited either east or west of the rocks of the combined Chatham-Giddings Brook slice. Combined the Chatham and Giddings Brook slices are 35 km wide at 42° N. The amount of tectonic shortening is unknown, but an original depositional site 50 km wide somewhere to the east (present compass direction as opposed to the south for late Precambrian time) appears to be the minimum distance necessary to accommodate these rocks. Ratcliffe (1969, 1974a) has shown that the rocks of the Chatham slice extend northward along the New York-Massachusetts line to connect with the belt of rocks shown as Dorset Mountain slice by Zen (1967, fig. 2) west of Pittsfield, Mass. This change is encorporated in Figure 1.

Everett slice

Rocks of the Everett Formation that form the high Taconic Everett slice at this latitude are greenish-gray, green, and locally purplish slate with relatively minor amounts of interbedded Rensselaer-like graywacke. In general the Everett resembles rock of the lower Nassau Formation when the effect of increased metamorphic grade is considered. Zen and Hartshorn (1966), Zen and Ratcliffe (1968), and Ratcliffe (1969a, 1974a, 1974b) consider the Everett rocks to be as old or older than rocks of the western slices. No fossils have ever been found within rocks of the Everett slice, and are not likely to be, so that the age problem may never be completely resolved. The Everett slice is about 12 km wide and probably originated from a depositional site at least this wide. Internal structure within the Everett slice, however, is poorly known, owing to the lack of coherent stratigraphy; the possibility of stacked slices of material that all rooted from the same zone could reduce this 12 km figure.

The contact relationships of the Everett and Chatham slices are complicated because the leading edge of the Everett slice is a zone of intense imbrication involving both allochthonous and autochthonous rocks. A belt of parautochthonous Walloomsac everywhere separates the two slices (fig. 2). Locally slivers several km long of purple and green slates typical of Chatham slice rocks are found encorporated in the parautochthonous belt of Walloomsac. In addition, at least two imbricate slices of Everett rocks are found above the Walloomsac sliver and above the slivers of Chatham slice rocks (Ratcliffe, 1974a).

The contact of parautochthonous Walloomsac on the Chatham slice and between the Everett and all other rocks is marked locally by an intensely developed tectonic breccia composed of inclusions of Stockbridge Formation. These breccias mark tectonic movement zones that differ from conventional fault zones in one important aspect. The carbonate clasts in the highly imbricated slate matrix are exotic blocks not derived from the present hanging wall or foot wall but from the autochthonous Stockbridge belt, and thus are considered tectonic inclusions transported within the movement zone from some site to the east. The tectonic breccia is evidence for a thrust beneath the Everett slice, which is independent of the regional stratigraphic arguments (Zen and Ratcliffe, 1966). These breccias have been mapped throughout southwestern Massachusetts (Zen and Ratcliffe, 1968; Ratcliffe, 1974a, 1974b) and are found in east and west dipping contacts as well as along the nose of plunging folds of the thrust contacts. The emplacement of the breccias predated the first regional metamorphism and the penetrative foliation that crosscut the contact of the thrust slices with the autochthon. Emplacement of the Everett slice resulted in brittle deformation (plucking) of the carbonate rocks, indicating that the carbonates were lithified at the time of thrusting. Similar brittle deformation of the pelitic rocks is not recognized, although an abnormally strong phyllitic foliation has been noted by Zen (1969) (see Stop 9, this trip) immediately adjacent to the carbonate slivers. It is commonly suggested, therefore, that the Everett slice was the result of hard rock thrusting because of these breccias. However, confirmation of the hard versus soft character of the allochthonous rocks must come from evidence in the allochthonous rocks. Thus far, clear evidence for brecciation is lacking, and the Everett slice need not have been completely indurated at the time of emplacement.

The age of emplacement of the Everett slice is unknown, but based on geometric relationships its final movements postdated emplacement of the Chatham slice in Middle Ordovician and predated formation of the regional slaty cleavage that probably is Late Ordovician in age (see Table 2).

A higher slice of Taconic-like rocks crops out near Great Barrington on June Mountain (Ratcliffe, 1974c) and on Canaan Mountain in the Ashley Falls quadrangle (Ratcliffe and Burger, 1975; Harwood, U.S.G.S. unpub. data, see Trip B-2). Rocks of this slice have a post (M_1) metamorphic emplacement fabric (Table 2), and Ratcliffe (1974c) suggests that these rocks are part of an extensive sheet of Taconic-like rocks that escaped gravity gliding and were thrust westward with the emplacement of the Berkshire massif in Late Ordovician(?). (See Trips B-2 and B-6). Importantly, these rocks have facies characteristics of both the Dalton and Hoosac and therefore probably represent the westernmost facies in the Taconic depositional basin because the Hoosac-Dalton-Cheshire sequences are connected by sedimentary interfingering (Norton, 1969).

The original depositional basin of the Taconic allochthon rocks at this latitude, based on the admittedly insecure arguments above, should have been in excess of 70 km wide. Palinspastic reconstruction of the Berkshire massif (see Trip B-6) suggests that the Precambrian crystalline rocks of the Berkshire massif, in the Middle Ordovician, were very likely about 60 km wide and located about 21 km farther east than their present position with respect to the miogeocline. The entire Taconic sequence could not likely have been deposited on the "basement" that was to become the Berkshire massif, as has generally been suggested (for example, Zen, 1967, 1968) because rocks of the Dalton-Cheshire-Stockbridge shelf sequence were deposited on at least the western 30 km of the gneiss (Trip B-6). Bird and Dewey (1970) suggested that much of the sequence was deposited to the east of the Grenville basement. The Taconic depositional basin probably was located largely to the east of the rocks making up the present Berkshire massif, and east of the Hoosac facies. This argument suggests that the root zone of the allochthon lies somewhere within the vicinity of the Hoosac-Rowe boundary east of the Berkshire massif (see Trip C-11). The Taconic rocks were probably deposited (initially) in an ensialic, evolving to ensimatic, basin, with graben and horst structure and basaltic volcanism (Bird and Dewey, 1970; Bird, 1975). Grenville gneissic components may have been derived largely from intrabasinal sources, as the spatial relationships of the Giddings Brook-Chatham and Rensselaer Plateau slices cited earlier require. If such a model is true and the comparison with Triassic rift basins is valid, the Rensselaer facies may have been deposited throughout a considerable period of time and may not be the oldest rocks of the allochthon as commonly assumed.

Metamorphic and tectonic events in the central Taconics of N.Y. and Mass.

Table 2 (reproduced from Ratcliffe and Harwood, 1975) presents the major tectonic features recognized in a 50 km east-west belt extending from Mt. Ida and the Giddings Brook slice eastward into the core of the Berkshire massif.

Structures associated with emplacement of the allochthon
D_1 - Phase A of Taconic orogeny

Large recumbent folds, such as Zen (1961) reported from the northern region of the allochthon, have not been found in the central Taconic region. However, Zen and Ratcliffe (1968), and Ratcliffe (1969, 1974a, 1974b) report the existence of prefoliation minor folds both in the autochthon and allochthon. Through recent mapping in the Chatham slice, Bahrami and Ratcliffe have noted that a wide range of bedding-cleavage intersections are found within individual outcrops. Steeply plunging, almost reclined axes of major and minor folds are characteristic of both autochthonous and allochthonous rocks. Figure 2 shows that a set of pre-foliation folds does exist in the Chatham slice, and quite probably this is the cause of the steep and erratic plunges noted. Rocks of the Giddings Brook slice (see Stop 1 and figs. 3 and 5) reveal similar steeply plunging F_2 fold structures. No evidence for truly recumbent folds has been found. Wildflysch-like conglomerates are found at the sole of the Giddings Brook (Stop 2) and Chatham slices (Stop 6).

<u>Phase B of Taconic orogeny</u>

Emplacement of the Everett slice (high Taconics) was marked by tectonic breccia zones that are distributed along the Everett-Walloomsac contact and locally between the Everett and Chatham slices (Stop 9). The emplacement of all of the Taconic slices at this latitude was premetamorphic, and no evidence

Deformational event	Number of fold system	Types of folds and areal extent	Important tectonic features	Metamorphic event	Important crystalloblastic and other structures	Igneous intrusion	Probable age of rocks in figure 1	Orogeny
D_6	F_6	North-south open folds of foliation locally recognized in Stockbridge valley	Northwest- and north-trending normal faults		Hematite-cemented breccias		Uncertain (Middle Devonian to Late Triassic)	
D_5	F_5	N. 25°–40° E.-trending upright to northwest overturned folds of foliation, with axial planar slip or crenulation cleavage. Folds recognized throughout area of figure 1 west to Mount Ida in SW corner of Kinderhook 15-minute quadrangle, N. Y., where Taconic unconformity is folded by N. 40° E. upright folds	Refolds thrust sheets and blastomylonitic foliation Chatham fault	M_2 Thermal maximum Acadian metamorphism	Crenulation of sillimanite alined in axial surface of F_4 folds; granulation of garnet and staurolite that includes F_4 foliation mylonite of Taconic foliation		Middle to Late Devonian (Ratcliffe 1969a, b, 1972) Ratcliffe, Bahrami (in press)	Acadian orogeny
D_4	F_4	Northwest-trending upright to southwest overturned folds with axial planar slip, crenulation, and flow cleavage. Folds recognized throughout area of figure 1, west to Chatham, N. Y., in center of Kinderhook 15-minute quadrangle	Folds thrust sheets and blastomylonitic foliation resulting in local overturning of thrusts; northwest-trending high-angle reverse faults		Muscovite, biotite realined and recrystallized in axial surface foliation; coarse sillimanite crystallized in foliation. Garnet, staurolite include folded F_2 fabric, and blastomylonitic foliation		Middle to Late Devonian (Ratcliffe 1969a, b, 1972)	
			Granite crosscuts thrust fault and blastomylonitic foliation	Thermal maximum Taconic metamorphism	Granite lacks blastomylonitic foliation in country rocks	Granite stock, South Sandisfield quadrangle	Late Ordovician(?) (Harwood, 1972)	Phases of Taconic orogeny
D_3	F_3	Northwest-trending recumbent to strongly southwest-overturned folds of basement gneiss and large-scale southwestward thrusting of Precambrian rocks of Berkshire massif across autochthon. Fold and thrust style recognized from Windsor quadrangle, Massachusetts (Norton, 1969), south to Norfolk quadrangle, Connecticut (Harwood, unpub. data), along west front of Berkshire massif	Faulted recumbent folds and nappes, mylonite gneiss, blastomylonite associated with major thrusts Thrust sheets at June and Canaan Mountains transported with Berkshire massif		Alaskite has weakly developed blastomylonitic foliation but intrudes more highly cataclastic rock in fault zones; mylonite gneiss, blastomylonite has muscovite, biotite, hornblende with lepidoblastic texture, cataclasis of F_2 foliation, thrusting synmetamorphic	Alaskite sills in faults and magnetite mineralization	Synchronous with latest movements or thrusts (Late Ordovician?) Thrusting probably late Ordovician based on age of cross-cutting granite	D
D_2	F_2	Isoclinal northeast-trending northwest-overturned to nearly recumbent folds with strong axial planar foliation which is dominant foliation in most autochthonous and allochthonous (Taconic) rocks, but not clearly present in Paleozoic rocks attached to Berkshire massif. Folds extend west to Mount Ida where unconformable beneath lowermost Devonian	Folding of Taconic thrust contacts, regional foliation and refolding of slump or soft-rock folds in Taconic allochthonous rocks	M_1	Lepidoblastic muscovite, chlorite, biotite, and ilmenite in foliation; chloritoid, albite include foliation but are kinked by F_4 structures		Middle to Late Ordovician(?)	C Taconic orogeny
D_2(?)	F_2(?)	Folding and metamorphism of Lower Cambrian metasedimentary rocks attached to Berkshire massif and in independent thrust slices at June and Canaan Mountains	Coarse foliation or schistosity formed	M_1(?)	Muscovite, biotite lepidoblastic in schistosity		Time of metamorphism very uncertain depending upon original position of these rocks, and timing of tectonic events at that site (Middle Ordovician to Cambrian?)	(C)?
D_1	F_1	Intrafolial minor folds associated with Taconic thrust contacts. Soft rock or slump folds in Taconic allochthonous rocks; scale of pre-F_2 folds not determined but widespread, area shown in figure 1, west to Mount Ida	Emplacement of upper Taconic slices (here, Chatham and Everett slices) Emplacement of lower Taconic slices	No metamorphism recognized	Tectonic breccias with inclusions of Stockbridge Formation along thrusts (Zen and Ratcliffe, 1971) Wild-flysch-like sedimentary rocks along base of thrusts		Uncertain (Middle Ordovician?) Middle Ordovician (Zen, 1972b, table 1)	B A
		Middle Ordovician unconformity						
D_0		Warping of Lower Cambrian to Lower Ordovician carbonate shelf sequence; locally dips near vertical (Ratcliffe, 1969a); possible block faulting					Late Early to Middle Ordovician (Zen, 1972b, table 1)	Pre-Taconic disturbance
		Pre-Dalton unconformity						
$D_{p€}$	$F_{p€}$	Isoclinal east-west-trending folds with generally steeply dipping axial surfaces and strong axial planar foliation; deformation of all Precambrian rocks including granitic intrusions such as Tyringham Gneiss	Gneissosity in Precambrian rocks of Berkshire massif	$M_{p€}$	Diopside, sillimanite, hornblende, microcline, perthite formed in dynamothermal event	Granodiorite-quartz monzonite intrusions such as Tyringham Gneiss, syntectonic	Dynamothermal event and granite intrusion approximately 1.04 b.y. (Ratcliffe and Zartman, 1971)	Grenville orogeny
		Pre-Tyringham foliation						

Degree of basement participation and intensity of deformation increasing with time

Table 2. Chronology of tectonic events in Columbia County, New York, and adjacent Berkshire County, Massachusetts. Modified from Ratcliffe and Harwood (1975).

is known in support of Bird and Dewey's (1970) suggestion that the Rensselaer Plateau and higher slices might have been metamorphosed prior to emplacement.

Phase C of Taconic orogeny (D_2 and M_1 Taconic metamorphism)

Following emplacement of all slices, regional dynamothermal metamorphism occurred, and a slaty cleavage or true axial planar foliation (S_2) formed in the rocks from the vicinity of Mt. Ida eastward into the area of the Berkshire massif and presumably beyond. In the low grade rocks, fine-grained sericite, chlorite, and lenticular quartz define the slaty cleavage. Small, round blebs of chlorite with 001 cleavage subparallel to bedding are ubiquitous in the low-grade rock and may be retrograded detrital biotite or diagenetic chlorite. However, lepidoblastic grains are not developed parallel to beds. Sandstone and siltstone dikes have not been found parallel to S_2, and no evidence thus far indicates that tectonic dewatering was an important mechanism in the formation of the Taconic slaty cleavage. Large finite strain is indicated by flattened pebbles that lie within the slaty cleavage. Locally, intense transposition structures are developed, and false bedding is common, particularly in laminated slates and some quartzites. Taconic thrust contacts of the Giddings Brook slice (Zen, 1961; Potter, 1972), Chatham (Ratcliffe, 1974a; Ratcliffe and Bahrami, in press), and Everett slices (Zen and Ratcliffe, 1968; Ratcliffe, 1968, 1974a, 1974b) were cross-foliated and folded during the D_2-M_1 metamorphic event to produce F_2 Taconic folds on a regional scale.

Phase D of the Taconic orogeny

Emplacement of the slices of the Berkshire massif and large-scale, westward overthrusting was concommitant with metamorphism. Recumbent folds formed both in the autochthon and in gneissic rocks (see Trips B-2 and B-6 for further amplification).

Acadian orogeny

Post-Taconic foliation structures are common throughout this belt and increase both in intensity and degree of concommitant mineral growth eastward. By using inclusion textures, we may delimit the approximate extent and character of the post-Taconic metamorphic imprint. East of the biotite isograd approximately at the New York State line post-S_2 mineral textures are abundant, indicating that the Acadian thermal overprint produced new mineral growth of muscovite (second generation with decussate texture), albite, chloritoid, biotite, garnet, and staurolite. It is fairly certain that the prominent mineral zonation is composite (polymetamorphic) and is dominantly controlled by the Acadian overprint in areas east of the biotite isograd. This probably explains the prevalence of Acadian K-Ar and Rb-Sr mineral ages (Zen, 1969) and the lack thus far of definitive Taconic mineral ages.

F_4 and F_5 folds are inconsistently developed and show contradicting relative ages from place to place. In eastern areas, the northeast-trending refolds are the F_5 folds, whereas in the low Taconics east to the Stockbridge valley the northwest-trending refolds are the later folds.

The Chatham fault developed during the northeast-trending refolding episode, for it is refolded by northwest crenulation folds north of Chatham (Ratcliffe and Bahrami, in press). Locally, thrust faults with mylonitization of pre-existing foliation and chlorite-quartz-albite mineralization formed in sections of the Chatham slice containing massive quartzite and graywacke (Stops 7 and 8).

In the Hudson valley the Acadian deformation resulted in brittle fracture and development of crenulation cleavage and slip cleavage in Taconic rocks, and flexural slip folds of the Devonian rocks with numerous bedding-plane and low-angle detachment thrusts. Acadian structures become progressively metamorphic to the east, so that in the vicinity of the Berkshire massif and farther east, Barrovian-type, staurolite-kyanite-sillimanite metamorphism was characteristic of the Acadian dynamothermal event; rocks of similar grade could also have been formed during the Taconic orogeny, but confirmation of this point is thus far lacking in the Berkshires. If the model proposed for the Chatham thrust is correct (fig. 6), then Acadian deformation could have involved basement in the Hudson valley area.

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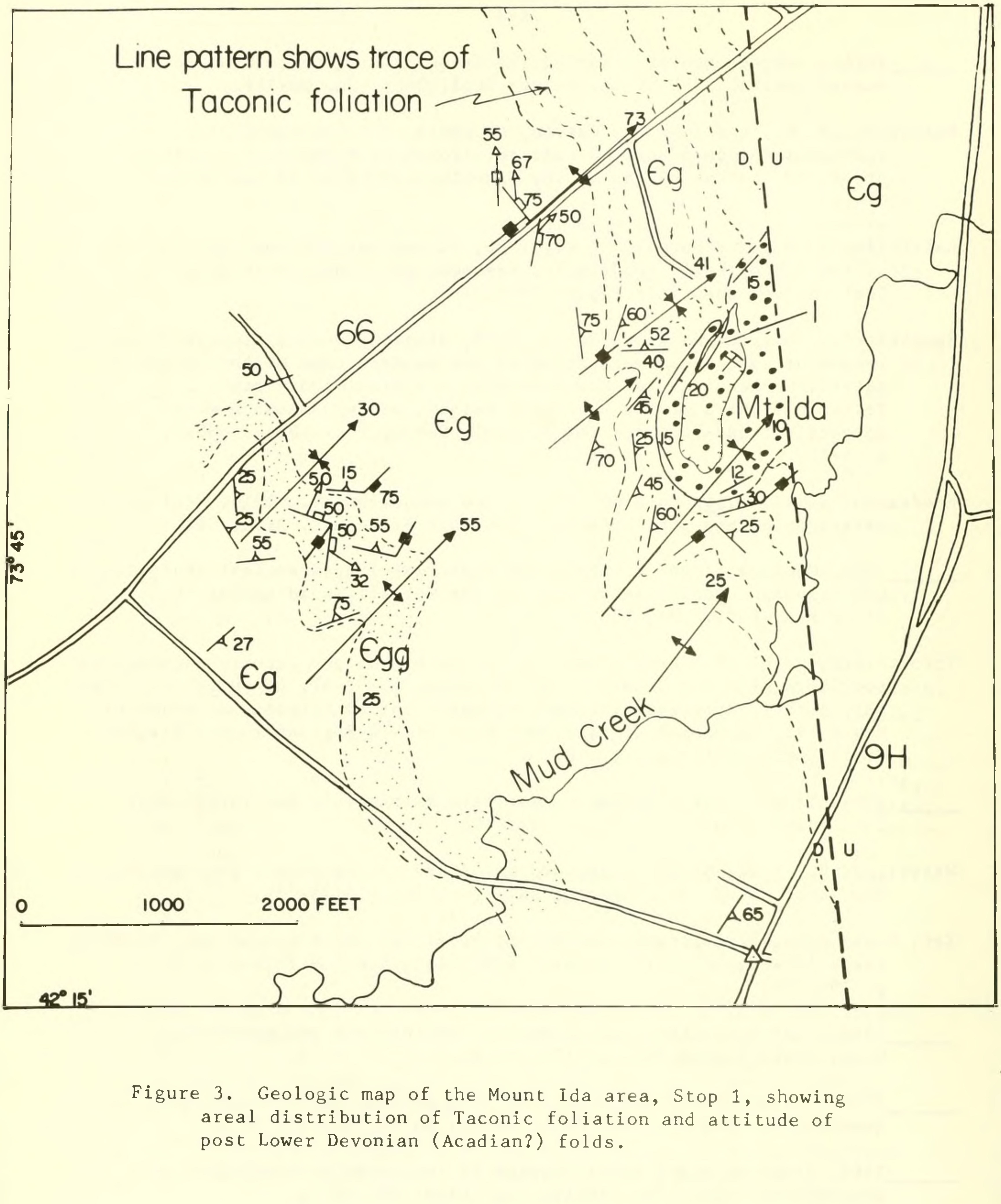

Figure 3. Geologic map of the Mount Ida area, Stop 1, showing areal distribution of Taconic foliation and attitude of post Lower Devonian (Acadian?) folds.

EXPLANATION

Silurian and Devonian

Dolostone and limestone

Taconic unconformity

Lower Cambrian

Єg Єgg

Germantown Formation with gray-green graywacke Єgg and associated limestone conglomerate

Contact between formations accurately located, approximately located

Strike and dip of bedding in Silurian and Devonian rocks

Strike and dip of pre-unconformity, penetrative foliation produced by parallel alignment of white mica, chlorite, and lenticular quartz, strike and dip of parallel bedding and foliation

Strike, dip of axial plane of pre-unconformity isoclinal folds having penetrative pre-unconformity foliation as axial plane. Arrow shows direction and amount of plunge of axis of fold (F_1 folds)

Strike and dip of inclined, and vertical post unconformity fracture cleavage that is axial plane to folds of foliation in pre-unconformity rocks, and approximately parallel to axial surface of folds in Silurian and Devonian rocks

Axial trace and approximate plunge of post unconformity folds of Taconic foliation (F_2 folds) and of initial folds of bedding post unconformity rocks

Approximate location of late high angle fault responsible for termination of Mt. Ida syncline, location and attitude conjectural

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Road Log

Assembly point Routes 66 and 9H, northeast of Hudson, New York (Brick Tavern), Stottville, N.Y., 7½ min. quadrangle.

Mileage

0.0 Head south on Rt. 66, 0.6 mile turn into Mt. Ida quarry at small yellow sign for Keil Contracting Corp. Drive to entrance to quarry and park.

Stop 1. Mt. Ida quarry and Taconic unconformity: discussion of Taconic and Acadian structures.

Mt. Ida is a small, fault-bounded syncline of uppermost Silurian and lowermost Devonian rocks, resting unconformably on slates of the Giddings Brook slice of the Taconic allochthon. Figure 3 shows the local geology.

Evidence for Taconic foliation and deformation

Dolostone of the Upper Silurian(?) Manlius limestone overlies slate of the Germantown "Formation" on the west wall of the quarry near the entrance. A limestone conglomerate 0-6 cm thick with chips of green slate forms the basal beds above the Taconic unconformity. The foliated chips contain a penetrative fabric outlined by oriented fine sericite, chlorite, and lenticular quartz that locally is normal to the postunconformity fracture cleavage, although most of the slate chips have been bodily rotated into parallelism with the Acadian cleavage. Although the pre-Manlius foliation commonly is parallel to the Acadian fracture cleavage, the foliated chips in the conglomerate document the existence of a Taconic penetrative, low-grade metamorphic fabric. Figure 4 shows photomicrographs of slate chips and Acadian(?) cleavage in the basal conglomerate. Outside the quarry (fig. 3) the Taconic slaty cleavage has been mapped as broadly discordant with Acadian fracture cleavage and bedding in the Siluro-Devonian rocks.

Acadian deformation

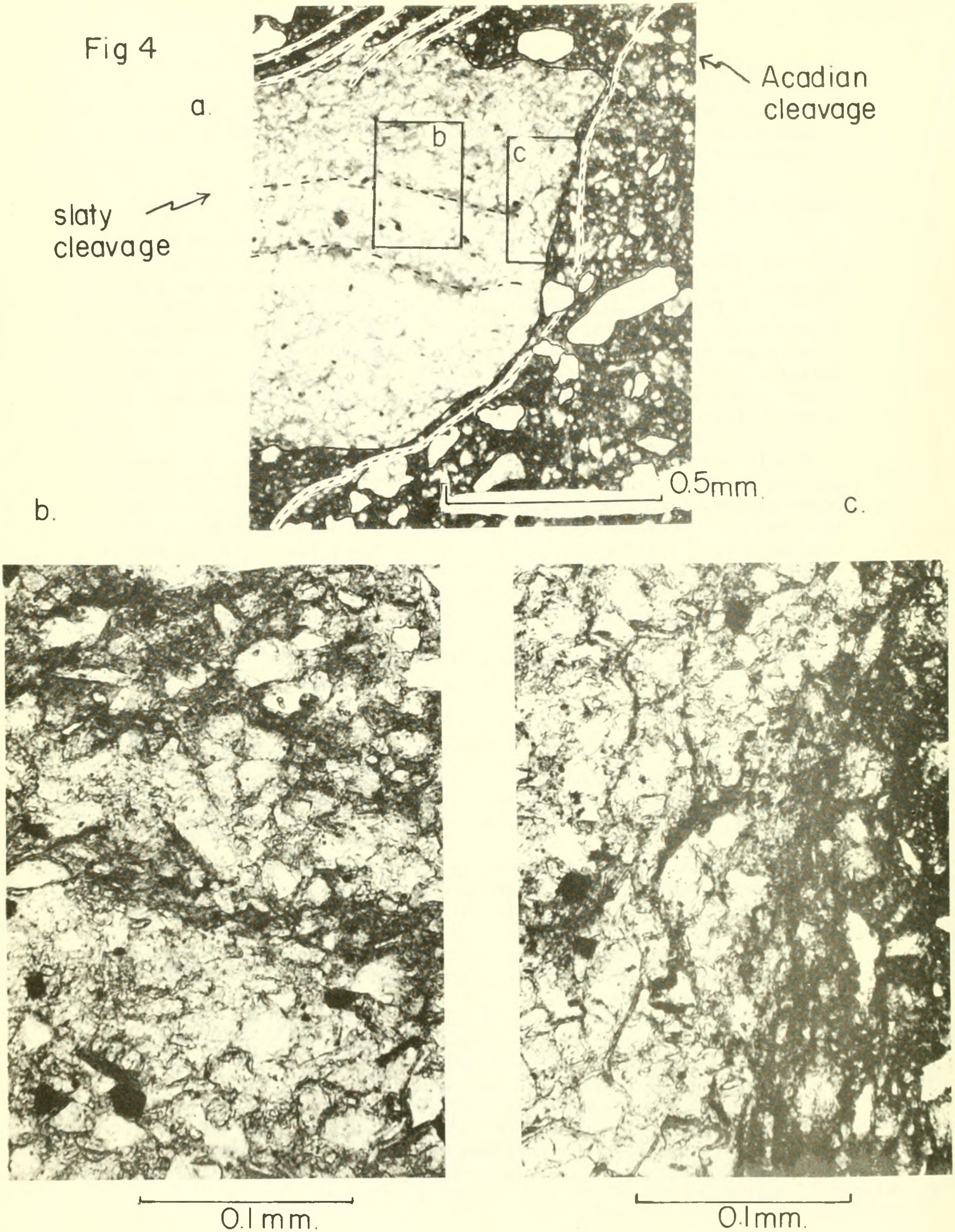
The Siluro-Devonian rocks and the unconformity are folded by broad flexural slip folds with abundant evidence of bedding plane slip. The age of this deformation is interpreted as Acadian because (1) folding in Devonian rocks dies out "upsection" in exposures west of the Hudson River, suggesting that the folding was pre-Upper Devonian, and (2) crenulation cleavage and post-Taconic foliation structures, when traced eastward, can be shown by metamorphic inclusion textures to be syn- or premetamorphic with respect to probable Acadian dynamothermal metamorphism (Ratcliffe, 1965).

A well developed fracture cleavage in the Siluro-Devonian rocks strikes N. 40° E. and dips steeply southeast. Immediately above the unconformity, thin seams of carbonate-rich silt intrude upward along the fracture cleavage for about a meter above as well as below the unconformity! Slate chips in the basal conglomerate also are bodily rotated without fracturing or bending, into a position subparallel to the Acadian fracture cleavage. Such rotation suggests a period of Acadian dewatering during or prior to flexural-slip folding. The origin of the alleged water (conate depositional water or sapprolitic from the slates) can also be debated on this outcrop.

Figure 4. Photomicrographs of foliated green slate chips in basal conglomerate of Late Silurian age, 6 inches above Taconic unconformity, Mt. Ida, Stop 1. Area of frames B and C outlined. Plane polarized light.

a. Shows slate chip surrounded by Upper Silurian quartz carbonate sand. Post-Lower Devonian fracture cleavage slopes from upper right to lower left and is outlined in white. Taconic slaty cleavage is horizontal.
b. Taconic slaty cleavage in slate chip, produced by fine grained sericite and chlorite concentrated in darker bands visible in (a) above.
c. Edge of slate chip, showing lepidoblastic chlorite and sericite and lenticular quartz re-oriented parallel to Acadian cleavage, shown in matrix. Texture implies that recrystallization of Taconic metamorphic minerals may have occurred locally in rocks as far west as the Hudson valley. Electron microprobe analysis of minerals will probably be necessary to demonstrate Acadian recrystallization rather than physical rotation of Taconic micas produced the new foliation. Micas similar to these are not found in the Silurian matrix.

Fig 4



Synopsis of Taconic and Acadian structures

Figure 5a, b, c, d shows structural data from the Mt. Ida area. In a, poles to foliation for the area of Figure 3 are shown, together with fold axes (open circles) of bedding with axial-planar slaty cleavage. The dashed small circle suggests the deformation path of these F_1 folds caused by Acadian rotation. Acadian fracture cleavage as measured in Devonian rocks (solid dots) and in Taconic slate (open dots) is shown in b. In c, the Taconic foliation measured beneath the unconformity has been restored by unfolding after taking out the plunge component of dip. The residual great circle configuration suggests the possibility of a weak, northwest-trending foldset (F_2? of diagram d). The synoptic diagram d shows approximate axial surfaces of the fold systems recognized. The pre-Manlius axial planes (slaty cleavage) were northeast-striking and steeply southeast-dipping, with fold axes (F_1) that plunge down the dip in nearly reclined folds prior to Late Silurian time. This pattern of steeply plunging F_1 folds is repeatedly seen throughout the Giddings Brook, Chatham, and Everett slices. Apparently these rocks contained rotated bedding prior to Taconic metamorphism and development of the slaty cleavage. This old structure may have formed during emplacement of the allochthon in the Middle Ordovician during a soft-rock (nonmetamorphic) event.

0.6 Log resumes at Rt. 66. Turn left (south) and proceed 3.4 miles south toward Hudson.

4.0 Turn right (west) on Rt. 23B at light and follow Rt. 23B through Hudson.

5.0 Turn left (south) on 9G and 23B. Follow signs to Rip Van Winkle bridge.

7.0 Roadcuts at Mount Merino 0.4 mile north of Rt. 23 intersection. Park off road or in parking lot east side of road near Rt. 23.

Stop 2. Wildflysch.

Zen (1961) proposed that the Giddings Brook and Sunset Lake slices of the Taconic allochthon were gravity slides and that the Forbes Hill Conglomerate of the northern Taconic region was a wildflysch facies that developed within the autochthon in response to the effects of the overriding submarine gravity slides (Zen, 1967). Subsequently, the wildflysch facies has been recognized along much of the western boundary of the Giddings Brook slice (Bird, 1969), and locally, along the eastern margin (Potter, 1972).

This stop is at one of the largest and best-exposed outcrops of the wildflysch in the Taconic region. It lies along the "front" of Mt. Merino, the "type-locality" of the Mt. Merino chert and shale (Ruedemann, 1942). Bird (1969) proposed that both Mt. Merino and a similar hill to the south called Mt. Tom (Mt. Thomas) are huge, detached blocks of the Giddings Brook slice within the wildflysch facies, because both hills are capped by Zone 12 and older rocks and, apparently, the wildflysch surrounds and projects under the hills. Bird also proposed that the Indian River - Mt. Merino facies is part of the Poultney Formation, not a member of the "Normanskill Formation", and that it is

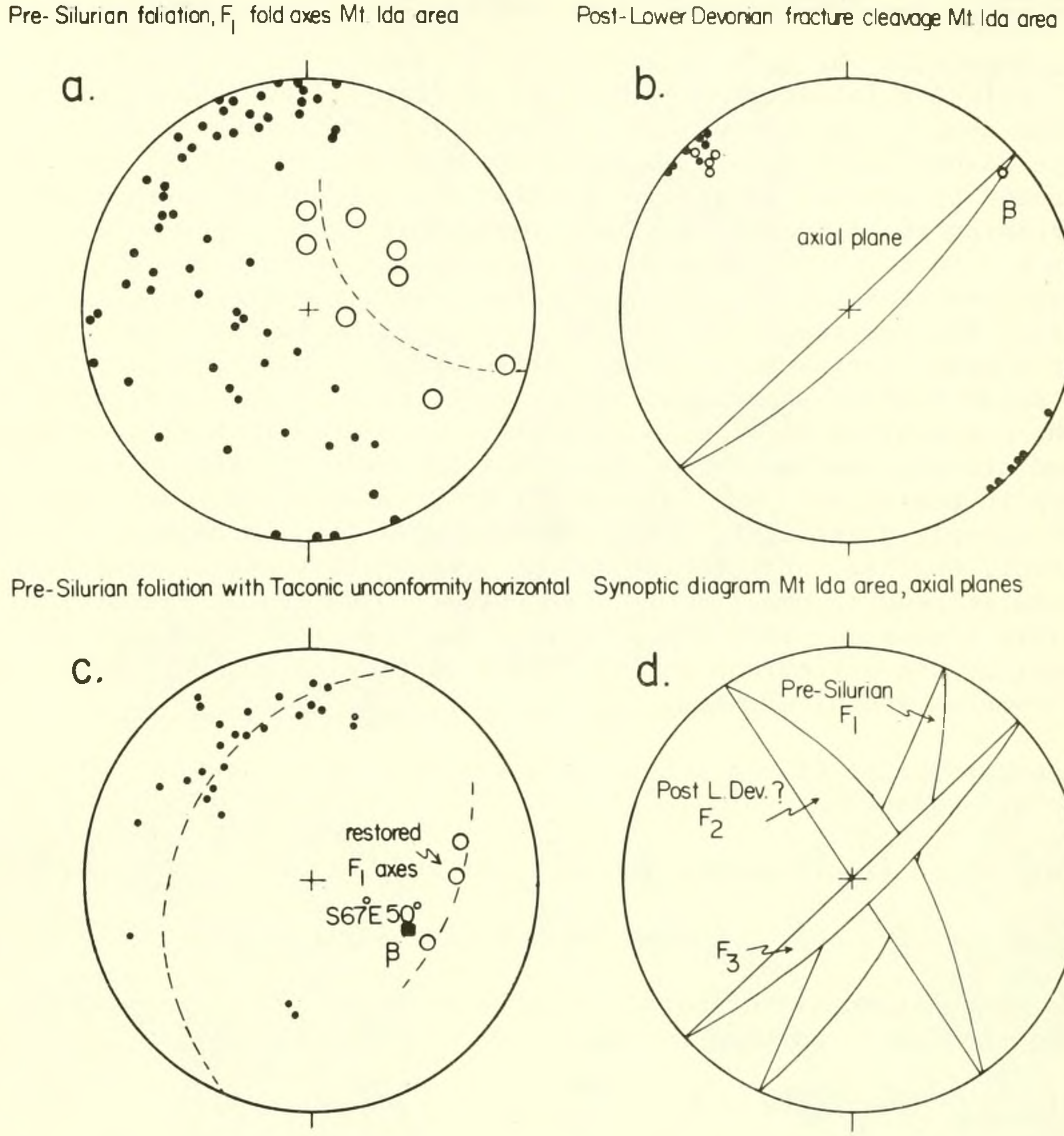


Figure 5. Lower hemisphere equal area projection of structural elements near Taconic unconformity, Mt. Ida, Stop 1.

a. Poles to pre-Silurian foliation area of Figure 3; large circles plunge of F_1 fold axes.

b. Acadian fracture cleavage in limestones open circles, crenulation or slip cleavage in Taconic slates solid dots, and axial surface and plunge of Acadian folds exposed in quarry.

c. Taconic foliation beneath 150 foot exposure of unconformity at west limb of syncline, with unconformity returned to horizontal, plunge component removed. Open circles F_1 fold axes restored, B pole to residual great circle, possible F_2 folds.

d. Synoptic diagram, axial surfaces Mt. Ida area. Nomenclature of F_1, F_2, F_3 is not intended to correlate with data on Table 1, where F_2 folds are equated with Taconic F_1 folds of this diagram.

entirely allochthonous, being the last facies to accumulate in the site of deposition of the Giddings Brook slice, before gravity sliding.

This exposure is within the belt of wildflysch that extends along the entire front of the Giddings Brook slice from southern Vermont to west of the Hudson Highlands (see Fisher, et al., 1971). In this region the wildflysch ranges from "soft-rock-deformed" Austin Glen graywacke and shale, to an extremely heterogeneous melange of the Austin Glen with included clasts of Giddings Brook slice lithologies. This exposure has inclusions of Mt. Merino chert, West Castleton - Hatch Hill(?) or Poutlney (Germantown - Stuyvesant of Fisher) bedded limestone and shale, and clasts of green Mettawee(?) shale. The rocks of this exposure are extremely complex and the trip leaders will attempt to point out relevant features. The exposure presents several questions: What are the cleavage relations of the shale matrix and clasts; did some of the clasts have a cleavage before incorporation into the melange: Note that some of the smaller Mt. Merino chert clasts must have been "soft" when deformed, and are not cleaved. Is all of the cleavage Taconic or is an Acadian cleavage also superimposed? Is the contact between the overlying, massive block of Mt. Merino chert and lighter colored melange, best seen on the southeastern end of the outcrop, characteristic of the overall nature of leading edge of the Giddings Brook slice?

The trip leaders believe that the overall character of the deformation of the wildflysch, the nature of the included clasts, and the distribution of the facies along the entire western edge of the Giddings Brook slice are ample evidence of Zen's original proposal. Detailed study of the wildflysch, particularly in the Hudson valley, has shown that apparently all the lithologies of the Giddings Brook slice, including Lower Cambrian fossil-bearing limestone clasts (Bird, 1963), and many lithologies of the carbonate sequence of the autochthon, especially Trenton-age facies such as the Rysedorph Hill Conglomerate, have been incorporated in the wildflysch which, <u>everywhere</u>, has a matrix of <u>only</u> the Austin Glen facies. No fossils other than Zone 13 graptolites have been found in the matrix. Therefore, emplacement of the Giddings Brook (and the very small Sunset Lake) slice as a huge, mostly submarine, gravity slide in Middle Trenton time is an established fact on the basis of the character and distribution of this most exotic, interesting facies.

7.2 Turn left onto Rt. 23 (east).

9.0 Junction Rt. 23 and 9 south. Continue on 23 and 9 east past south end of Becraft Mountain.

12.0 Road branches. Take left branch and follow Rt. 23 and sign for Taconic Parkway. Avoid Rt. 9 branch to right. Dangerous intersection.

12.2 Turn left (north) on Rt. 9H and 23 at light. Follow 9H and 23 north to Claverack.

16.0 Turn right (east) on Rt. 23 at light by Claverack Texaco station.

17.0 Turn left on Rt. 217, 1 mile east of Claverack and follow Rt. 217 3 miles north to Mellenville.

20.0 Mellenville, 500 ft. past Costa's store turn left up hill on unmarked road that leads to Columbia County Rt. 9 (do not cross creek into Philmont). Follow Col. Co. Rt. 9, 2 miles north to second crossroad north of Mellenville.

22.0 Turn right on paved crossroad, and follow road approximately 2 miles (go beneath RR overpass) to Stop 3. Park at top of hill.

Stop 3. Ghent Precambrian gneiss block and attached unconformable shelf sequence rocks, within the Chatham fault zone.

This remarkable and instructive exposure was recently discovered by Ratcliffe in 1973. Previous workers (Craddock, 1957; Fisher, et al., 1971 /after Craddock/) did not recognize the gneissic or shelf sequence rocks here but show the Chatham fault at this locality juxtaposing green slates and graywackes of the Nassau Formation (Fisher, et al., 1971).

Grenville-like alaskitic gneiss, hornblende granite gneiss, hornblende diopside plagioclase gneiss, amphibolite, diopside calc-silicate, all crossed by thin pegmatitic stringers, form an elongate sliver (1,000 feet long and 500 feet wide on the east side of the main Chatham fault). The western border of the gneiss (Chatham fault) is marked by mylonitic and highly cataclastic gneiss with east-dipping shear zones in the hanging wall and highly deformed, crenulated, and mylonitized olive-green slate and metaquartzite in the foot wall (seen at base of hill north of road).

Along its east and south border the gneiss is unconformably overlain by east-dipping, white to pinkish-gray vitreous quartzite (Poughquag?) with a basal quartz-pebble conglomerate south of the road and up the hill.

The quartzite, about 70 feet thick, is overlain by gray to white dolomite (Stissing Formation?) 100 feet thick, and this in turn is overlain by up to 600 feet of beige and orange-tan weathering dolostone with punky weathering quartzite typical of the Pine Plains Formation. If the lithologic correlations are correct, the Paleozoic shelf sequence of the block may range from Early to Late Cambrian in age. Along the east side of the sliver, gray to gray-green and olive slate of the Nassau Formation with graywacke beds up to 50 feet thick are thrust over and truncate the shelf rocks, and locally a small sliver of Walloomsac intervenes. Both rocks are cataclastic with gentle (35°) east-dipping fractures and microfaults that cross the regional foliation.

Ratcliffe and Bahrami believe that the Chatham fault is a late tectonic feature based on the distinctive cataclasis of Taconic foliation in and near the fault zone along its entire width. They suggest that the Chatham fault is a major postmetamorphic thrust with a minimum of 3.5 km dip slip movement necessary to bring the gneissic basement to its present position. The Ghent block may have been moved up in the fault zone by a stepwise set of faults as shown in Figure 6, or could have been plucked from a pre-Middle Ordovician age horst that was located somewhere east of the present trace of the fault. The Chatham fault actually is a very complex fault zone that contains large slivers of allochthonous Giddings Brook and Chatham slice rocks, all intermixed with blocks of Precambrian gneiss, Cambrian to Ordovician shelf sequence, and exogeosynclinal Middle Ordovician rocks from the autochthon, within a mylonitic matrix produced by granulation of all of the pre-existing metamorphic rocks.

A primary contact between the Giddings Brook slice and the Chatham slice has not been found and quite possibly does not exist. Postmetamorphic faults have not generally been recognized in the Taconics, but it appears that some of the major boundaries used to delineate separate slices of the Taconic allochthon (Zen, 1967) might be Acadian or younger structures. One might well wonder if this is Stissing Mountain in microcosm!

Continue east on dirt road.

25.0 Turn right at "T" intersection.

26.0 Park by bend in road one mile south at woods road leading to the west. (Outcrops are down the hill, 800 feet west of the road.)

Stop 4. Ashley Hill-like Limestone Conglomerate, West Castleton-Hatch Hill sequence, east of the Chatham fault.

Limestone as interformational and boulder conglomerate is widely developed west of the Chatham fault in rocks of the Giddings Brook slice (Zen, 1967; Bird and Rasetti, 1968) but only rarely east of the fault, as near Philmont (Weaver, 1957, p. 745) and this new locality discovered by Bahrami. As originally illustrated in Craddock (1957), the well known Ashley Hill Limestone Conglomerate (AHLC) (Dale, 1892) lies east of the Chatham fault. However, Zen (1967, p. 20) placed the Ashley Hill locality within the Giddings Brook slice (west of the Chatham fault) based on relocation of the fault by Talmadge (written communication to Zen, 1962).

This sliver, 4 km long and about 6 km wide, is located east of the west edge of the Chatham fault and illustrates imbrication into the Chatham fault of strata characteristic of the Giddings Brook slice.

The exposures here consist of limestone boulder conglomerate interbedded with black shale and dark-gray, fine-grained, well-bedded limestone, and punky-weathering, calcareous, crossbedded quartzite. Crossbeds indicate the east-dipping sequence is right-side-up. Green slates with quartzite and interbedded graywacke underlie the limestone and black slate. The contact or zone between these two lithologies is the "black-green boundary," a homotaxial surface that can be seen in this part of the section throughout the Giddings Brook slice (eg. Zen, 1964b). It is the defined contact between the base of the West Castleton-Hatch Hill sequence, which comprises the bulk of the fossiliferous

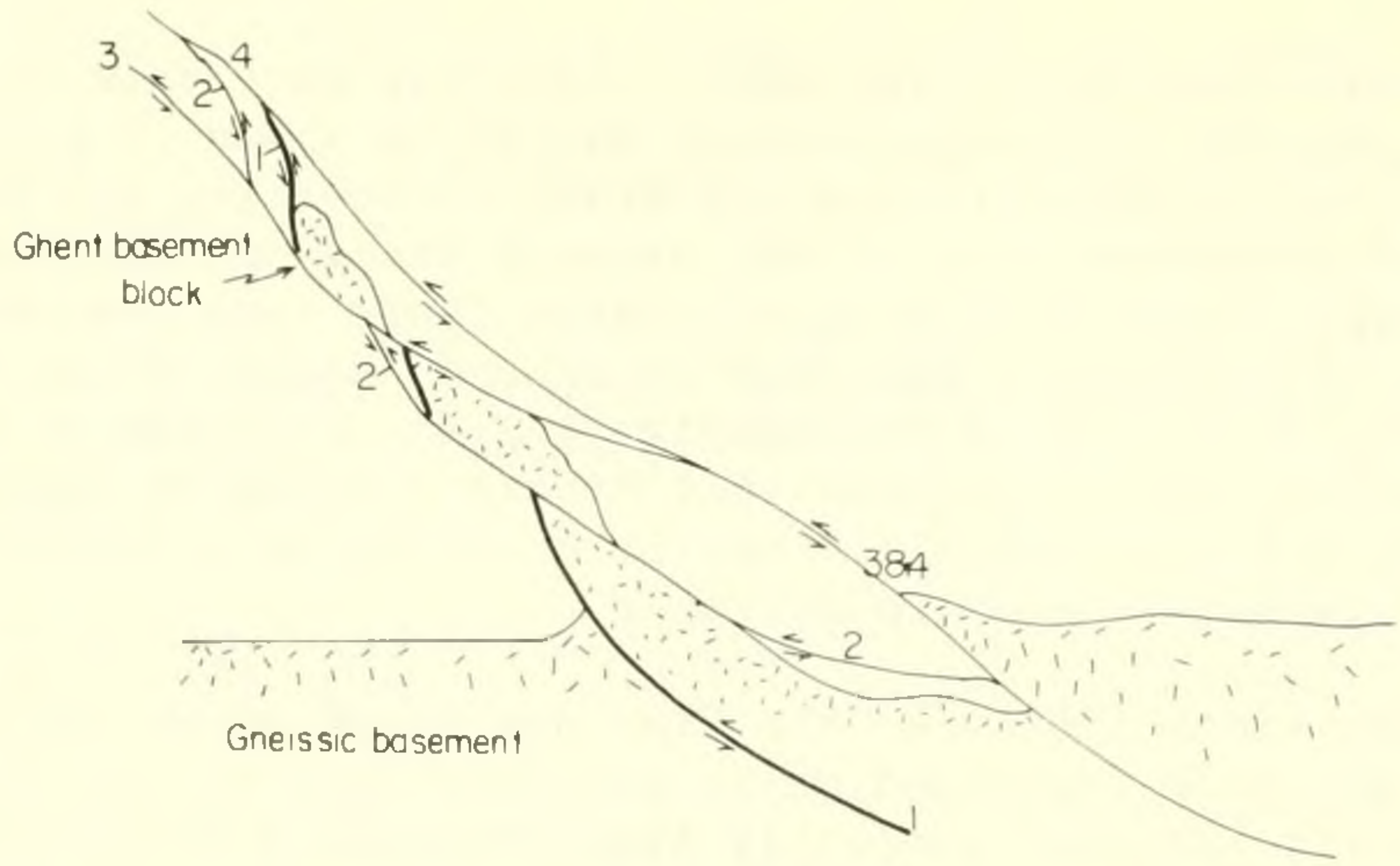


Figure 6. Diagram of possible mechanism for emplacement of the Ghent block. Numbers refer to sequentially developed faults. Slivers of shelf sequence rocks and Taconic allochthonous rocks would also move upward to produce a complex fault zone with interwoven slices of material initially plucked from widely different tectonic levels. Later faults need not offset basement but could be low angle detachment faults.

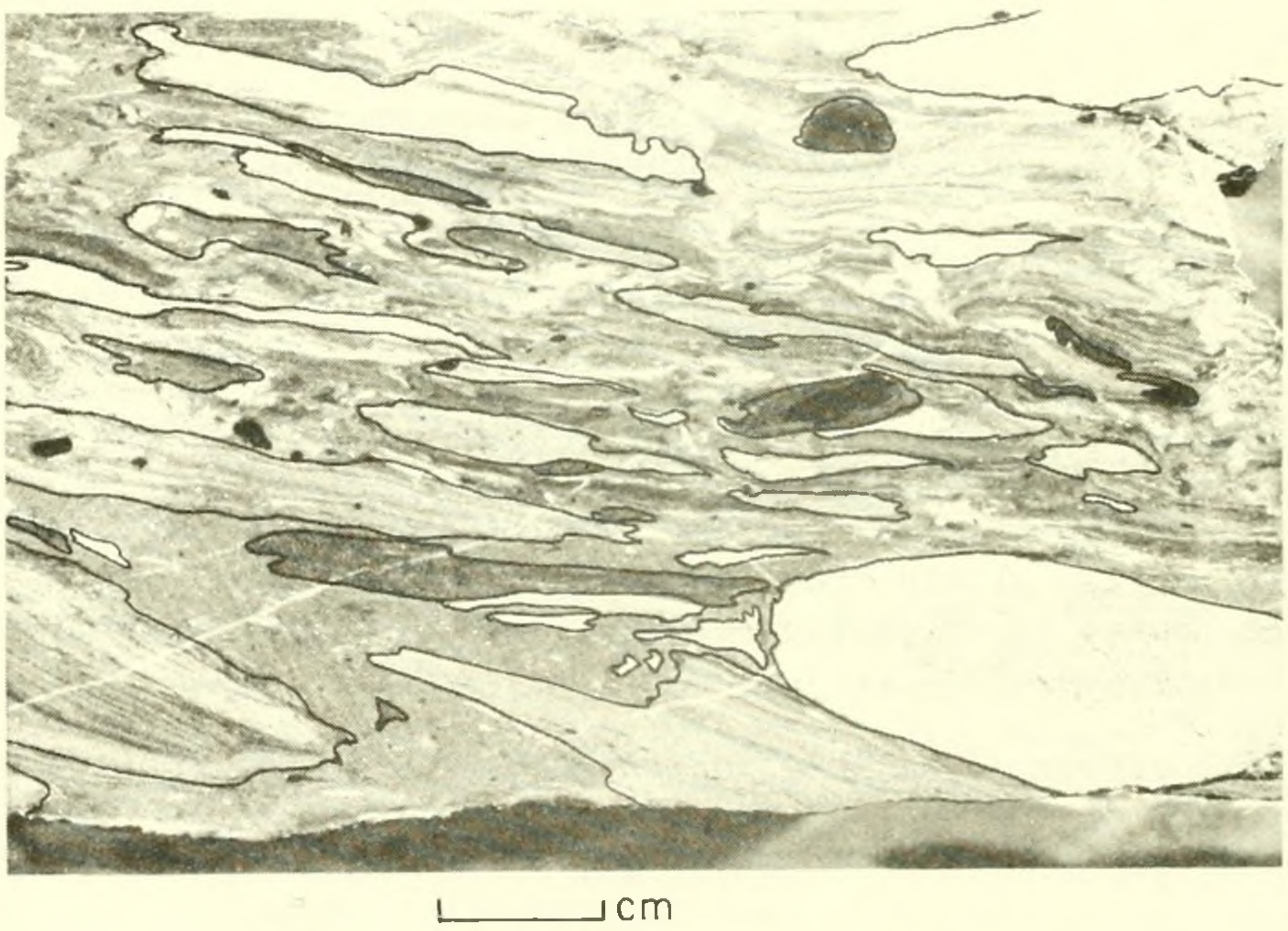


Figure 7. Sawn slab of wildflysch-like conglomerate from sole of Chatham slice, inclusions of gray-green slate, black slate in a nonbedded to well laminated gray slate matrix, Stop 6. Some of the more obvious inclusions are outlined in black. The localization of this feature at the Walloomsac-Nassau contact and the nature of the clasts suggest that the rocks of the Chatham slice were unlithified at the time of emplacement.

Cambrian strata, and the top of the Nassau or Bull Formation that comprises the bulk of the pre-fossiliferous, or Eocambrian strata. The green slate is Mettawee of the Nassau Formation; the black slate is of the West Castleton Formation. Lower Cambrian fossils occur in the Ashley Hill Limestone Conglomerate and the Mud Pond Quartzite (at Diamond Rock, Troy, N.Y.), which are facies that occur at, above, and below the "black-green boundary." These relations (and sources of data) are shown in Table 1, where a schematic columnar section that is "constructed" for Giddings Brook and Rensselaer Plateau slice rocks. It must be emphasized that, in contrast to the relatively straightforward stratigraphy upsection from the black-green boundary (Mt. Hamilton Group of Zen), we do not have a firm grasp of the actual stratigraphic relations downsection. For example, although Rensselaer Graywacke facies occurs in the lower part of the Nassau Formation in the type-locality of the Nassau quadrangle (Bird, 1961, 1962a, 1962b, 1969), the bulk of this facies, which is in the Rensselaer Plateau and Austerlitz masses, is within geometrically high structural units that have been telescoped from the original stratigraphic configurations and do not have the higher fossiliferous sections attached. Future work in the Taconics will certainly include determining the very complex palinspastic reconstructions of the Eocambrian-Cambrian rocks across such major tectonic features as the Chatham fault.

Continue southward on dirt road 0.4 mile.

26.4 Turn left (east) on Rt. 217.

27.0 Turn north on Taconic State Parkway (right turn under overpass).

28.0 Turn into rest area, east side of northbound lane of T.S.P. Stop 5 and lunch stop. Participants without lunch or in need of fuel may proceed northward on T.S.P. for 2 miles to Rigor Hill Rd. where there is a diner and Shell station. We will pick you up there in ½ hour.

Stop 5. Volcanic-polymict conglomerate and subgraywacke in the Nassau Formation. Park at turnoff from Taconic Parkway and walk 200 feet east. This is the first of three stops to examine Rensselaer-like facies of the Nassau in the Chatham slice.

Massive, dull-white weathering subgraywacke with a distinctive polymict basal conglomerate overlies gray, well-laminated slate. The pebbles in the conglomerate consist of (a) well rounded, garnet and zircon-bearing, white metaquartzite, (b) angular, dull, reddish-brown weathering, hematite-rich, glassy volcanic rock with irregular, globular textural variations suggestive of magma-filled vesicles, and microlites of plagioclase 0.1 mm in length that show a well defined flow structure, and (c) dull greenish-gray aphanitic or felsitic andesite(?) with microclites of plagioclase, quartz, and green hornblende(?). Rock (b) above probably is highly oxidized basaltic or andesitic scoria, perhaps the surface of andesitic flows (b) or of pyroclastic fragments.

The garnet-bearing metaquartzite is a typical Grenville rock in the Adirondacks, Green Mountains, and Berkshire massif (Washington Gneiss). A conglomerate similar to this, described by Balk (1953, fig. 6), also contains black tuffaceous(?) fragments. Volcanic rocks are minor but important components of the Nassau sequence in the Rensselaer Plateau and Chatham slices and locally in the Giddings Brook slice (North Petersburg slice of Potter, 1972).

The mixture here of subgraywacke, well-rounded Grenville gneiss pebbles and fragmented, nonabraded volcanic fragments in a coarsely-graded lag deposit requires a special environment of sedimentation. Perhaps we are looking at sediments derived from fluvial environment, deposited in a basin made up of horsts and graben with active faults and basaltic volcanism. Bird (1975) suggested that the Rensselaer of the Nassau sequence represents a graben facies developed during the initial opening of the proto-Atlantic ocean basin (Bird and Dewey, 1970). In the context of that model Rensselaer Graywacke facies can be compared with those of the Triassic rocks of the Newark basin and Connecticut Valley. The Triassic rocks are fluviatile, shallow marine sediments and volcanic rocks, which developed synchronously with faulting attributable to the initial rifting of the present Atlantic ocean basin (Bird and Dewey, 1970).

30.0 Proceed north on T.S.P. for 2 miles to Rigor Hill Rd., where we will reassemble and pick up lunchless and/or gasless participants. Continue north on T.S.P. for 4.5 miles to intersection Rt. 203.

34.5 Exit for Rt. 203 east (turn right).

34.8 In 0.3 mile turn left at first intersection at Moorehouse Corner onto Columbia Co. Rt. 9 and follow paved road 2.5 miles to intersection with Columbia Co. Rt. 24.

37.3 Turn right on Col. Co. Rt. 24 at "T" intersection. Follow Rt. 24 0.9 mile east. Park before first barn on the right.

38.2 Stop 6. Nassau-Walloomsac "Taconic thrust" contact and wildflysch-like micromélange at sole of Chatham fault, Sheep Hole, Indian Brook, Red Rock.

Exposures of black Walloomsac in the brook are well-foliated with folds of bedding and bedding cleavage lineations plunging southeast at about 25°. Upstream, green phyllite of the Nassau overlies the black slate. Near the contact a zone several meters wide of mixed rock intervenes. Fragments of black slate in peculiar open ended forms float in a matrix of green slate, and both host and inclusions are strongly crossfoliated (fig. 7).

Unlike conventional wildflysch, this mélange consists of black chips (probably Trenton) in a green matrix probably of earliest early Cambrian or Eocambrian age. Locally this texture may be reversed with black and green chips set in a predominantly black Walloomsac matrix. This curious deposit has only been found at three localities, all within several meters of the sole of the Chatham slice. Although this is not a normal sedimentary-tectonic deposit, it could represent a zone of disarticulation and comingling of rocks within a zone of intense differential flow, formed at the sole of the Chatham thrust coeval with wildflysch produced to the west at the leading edge of the slide. The encorporation of fragments of both rocks in the mélange without a cataclastic (brittle) fabric suggests soft rock deformation. This is the best evidence known to the authors suggesting that the Chatham slice was emplaced by a soft rock gravity slide mechanism similar to the Giddings Brook slice.

The contrast between the Chatham thrust (Stop 3) and this Taconic thrust contact is striking. The bulk of the contacts of the Chatham and Everett slices with the autochthon are premetamorphic.

Continue 0.6 mile east on Col. Co. Rt. 24 to Red Rock.

36.8 Turn right onto Macedonia Rd. Follow 0.8 mile to first major stream crossing.

39.6 Stop 7. Rensselaer graywacke contact with purple slate of the Nassau.

Large exposures of typical Rensselaer graywacke in the streambed overlie purple slate at the base of the waterfalls. The contact locally is a fault that is marked by pods of bull quartz, with alkali feldspar and veinlets of chlorite. These postmetamorphic faults are very common wherever massive units such as graywacke and/or quartzite are in contact with more ductile units. Two hundred feet north of the falls the purple slate is in sedimentary contact with the graywacke. Although these mylonitic, mineralized zones are spectacular and suggest megatectonic activity, usually they involve insignificant throw. This kind of deformation and mylonitization on low angle thrusts probably is the result of "bedding plane slip" during Acadian folding of rock sequences having high ductility contracts. In thin section irregular veinlets of chlorite, often wedge shaped, crosscut the older foliation. The chlorite commonly has a strong crossfiber fabric not related to either the older or later foliations. This behavior contrasts markedly with the similar style of folding and penetrative deformation active during Taconic metamorphism, as seen at the next stop.

39.7 Continue south on Macedonia Rd. 0.1 mile. Bear right staying on Macedonia Rd.

39.8 Intersection of Stonewall Rd. Continue on Macedonia Rd. for 1 mile.

40.8 Turn left at "T" intersection onto Reed Rd.

42.5 Intersection with Rt. 203. Turn left onto dirt road (Big Wood Rd.) that parallels 203.

42.9 Park before town dump.

Stop 8. Graywacke conglomerate and postfoliation thrust fault, west edge of the Austerlitz outlier of the Rensselaer graywacke.

Park on old Rt. 203 near gravel pit and walk up slope to north, 2100 feet to outcrop of graywacke at west draining brook. From this point head N. 70° E up slopes toward north end of hill 1356.

Large cliff exposure (Balk, 1953, Fig. 5, p. 825) exposes a 25 foot thick lens of the coarse graywacke conglomerate overlying a dark-gray to purplish-gray slate on an east dipping thrust fault. The boulders are flattened in the plane of the slaty cleavage (Taconic foliation). Numerous nearly reclined "S" folds of foliation and secondary segregations of quartz and veinlets of dark-green chlorite, quartz, and pink alkali feldspar form a mylonitic zone, with a downdip mineral lineation. Postfoliation thrust faults and mylonite zones with strong downdip chlorite streaking and bull quartz resemble some of the exposures cited by Potter (1972) as evidence for mylonitization along the sole of the north Petersburg and Rensselaer Plateau thrusts.

The conglomerate is polymict with Grenville(?) gneissic boulders, white calcite marble, layered amphibolite, black chert, reddish quartzite, and numerous large chocolate-brown weathering calcarbonate-rich rock. Fragments of Rensselaer graywacke and one small cobble of graywacke conglomerate can be found. Locally, diabasic volcanic fragments (Balk, 1953, Pl. b, fig. 3) identical to the basalt flows near Fog Hill in the State Line quadrangle (Ratcliffe, 1968, 1974a) are included in the graywacke, indicating the contemparaneity of the volcanism with deposition.

The brown weathering limey cobbles are not represented anywhere in the sub-Rensselaer stratigraphy of either the Giddings Brook or Chatham slices or in the shelf sequence. They could represent a fine grained retrograded Precambrian marble or a limestone of unknown origin.

The mixture of autoclastic debris (graywacke clasts, limestone?, and volcanics) with probable Grenville clasts suggests that the Rensselaer may indeed have been deposited as a "Newark like" graben facies attendant to late Precambrian rifting as Bird (1975) suggested. The extreme coarseness of this deposit and the heterogeneous mixture suggest some kind of debris flow mechanism.

Fine grained sedimentary dikes (of graywacke) irregularly intrude gray-green slates in excellent exposures 300 feet along the slope to the north. This probably resulted from abnormal pore pressures resulting from rapid sediment loading of coarse debris flows onto uncompacted shales and graywackes. Balk also reported sedimentary dikes in the Rensselaer northeast of Troy (Balk, 1953, pl. 3).

43.3 Continue east and turn left on Rt. 203 in 0.4 mile.

45.9 Intersection with Rt. 22 at Austerlitz. Turn right (south). Hills east of Rt. 22 are sapped by rocks of the Everett slice that overlie the Walloomsac. West of the highway fault slices of Everett cap the higher hills, and locally the Everett extends down to the road. The belt of Walloomsac in the valley is parautochthonous and has been thrust westward over the Chatham slice.

47.0 A marked bench 3/4 way up the slopes to the east of the road marks the location of a prominent carbonate tectonic breccia zone at the sole of the Everett slice. A detailed map of this locality was published in Zen and Ratcliffe (1966).

48.9 Intersection with Rt. 71. Bear left on 71 toward Great Barrington. Hills to the right are imbricate and folded slices of Everett interleaved with tectonic breccia and slivers of parautochthonous Walloomsac.

50.3 Turn right onto Overlook Rd., opposite the Green River Inn.

51.9 Stop 9. Tectonic breccia at sole of Everett slice. Discussion of the Everett slice. Park near T.V. tower. Exposures are in woods above pasture east of road.

Tectonic breccias at the base of the Everett slice include fragments of Stockbridge carbonate rocks, Walloomsac limestone and phyllite, and fragments of Everett intermixed in a complex zone locally up to 100 feet thick. Zen and Ratcliffe (1966) believe these inclusions were plucked from the underlying autochthon during emplacement of the Everett slice and physically dragged along beneath advancing thrust. All units of the Stockbridge and Walloomsac are represented in these breccia zones, although no autochthonous rocks older than unit a of the Stockbridge have been found. This is the best exposed large outcropping of the breccia in southwestern Massachusetts. Zen's 1969 N.E.I.G.C. trip visited this locality (Stop A6). Detailed geology is available in Zen and Ratcliffe (1971). Zen has new information about the mineral assemblages and their isotopically determined ages that he has kindly consented to discuss at this stop.

The breccia zone is exposed east of the road in the core of and on the eastern limb of a northeast-plunging anticline (fig. 2). West of the road green Everett phyllite is found in the core of the complementary syncline rimmed by the tectonic breccia. This western belt of breccia traces northward into the State Line quadrangle beneath a belt of Everett that is the highest of a series of imbricate slices at the leading edge of the Everett slice. The anticline-syncline pair have an axial surface that strikes N. 10° E. and dips 60° to 65° southeast parallel to regional foliation. Bedding cleavage lineations plunge downdip or to the northeast in a style similar to the F_1 folds seen to the west.

Examination of the contacts of the marble inclusions with the Everett and the Walloomsac shows that the earliest foliation parallels the contacts on the limbs of minor folds and crosscuts the marble-phyllite contact on the noses of folds. The fabric here and elsewhere in the Everett-related breccia zones differs from that found in the Chatham fault, Stop 3, where contacts of limestone and other inclusions postdate the foliation.

Secondary plications of foliation and a fairly well developed second foliation, dipping more steeply east than the first foliation, is not developed or concentrated at the contact of the carbonate inclusions. Ratcliffe's interpretation, which may differ from that of Zen (1969), is that the breccia zone was emplaced prior to rather than synchronous with the structural event that produced the first regional foliation (Taconic). Ratcliffe believes the overall highly folded geometry of the breccia zone about the early axial planes requires this interpretation.

Metamorphic textures in the Everett at this locality (Zen, 1969) and on strike in the State Line quadrangle (Ratcliffe, 1965, 1969) indicate that second generation muscovite, zoned albite, chloritoid, and zoned garnets poikiloblastically include both an older foliation and micro-crenulations of it, and are locally crystallized across micro-offsets of the slip cleavage. East of the garnet isograd, new biotite and muscovite lie in new foliations that are the axial plane of the F_4 and F_5 folds of Table 2.

Ratcliffe believes that these textures indicate a petrographically definable zone of Acadian overprinting. The intensity of the over-printing, as indicated by the mineral growth textures, suggests that the K-Ar and Rb-Sr ages available probably record the effect of the Acadian thermal history, and older Taconic minerals, if preserved at all, should yield hybrid ages.

Excellent exposures illustrating the polymict nature of the tectonic breccia may be seen east of the pasture in the west-facing ledges. Magnificent 3-dimensional, crawl-around exposures of marble inclusions are preserved in small caves near the south end of the ledges.

End of trip.

Return to Rt. 71. Turn right and follow to Rt. 23; turn left on Rt. 23. Turn left on Rt. 9 for Great Barrington.